Dynamic performance Improvement Of SPWM-VSI

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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In

ELECTRICAL ENGINEERING

By

MAYADHAR MUDULI (110EE0046)

ASHOK KUMAR SHARMA (110EE0565)

Under the guidance and supervision of

Prof. Somnath Maity

Dept. of Electrical Engineering

NIT, Rourkela

Dept. of Electrical Engineering
National Institute of Technology Rourkela,
Rourkela – 769008,
India

Department of Electrical Engineering
National Institute of Technology
Rourkela - 769008
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CERTIFICATE

This is to certify that the thesis entitled, **"Dynamic Performance Improvement Of SPWM-VSI"** submitted by **Mayadhar Muduli (110EE0046)** and **Ashok Kumar Sharma (110EE0565)** in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Electrical Engineering at the National Institute of Technology, Rourkela (Deemed University) is a genuine work carried out by them under my sole supervision and directed guidance.

To the best of my understanding, the material embodied in the thesis has not been given in to any other University / Institute for the reward of any Degree or Diploma.

Professor Somnath Maity
Department of Electrical Engineering
National Institute of Technology
Rourkela – 769008

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Mayadhar Muduli

Ashok Kumar Sharma

CONTENTS

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ABSTRACT

Power Quality Improvement has been a serious concern in all fields at all times .Improving the quality of the supply waveform free from any distortion like harmonics or any deviation from the ideal characteristics has let our attention to be devoted to the development of suitable methodologies. Henceforth, we have designed the inverter system which converts the DC into AC voltage which is a pure sine wave, with the voltage and frequency of the standard grid output. The system consists of a full bridge inverter circuit with a passive filter, a feedback circuit using a PI controller and a comparator circuit which gives switching pulses. Our basic intention here is to increase the dynamic performance of the inverter. Suitable modulation techniques and processes have been selected and implemented for the best results. The error in the output signal is minimized for both inductive and capacitive load by the closed loop control scheme that ensures suitable harmonic elimination technique to achieve better performance of the inverter output waveform. The design of LC filter along with suitable change of parameters has been duly studied for better stability and hence evaluated with due simulation. Concerned efforts have been made and will improve further for the betterment of the stability of the system.

LIST OF FIGURES

CHAPTER 01

INTRODUCTION

CHAPTER 1: Introduction

We want a sinusoidal voltage waveform which is of constant magnitude and frequency as an ideal electric supply. However, the reality is most of the time different due to the non-zero impedance of the supply system, of the great variation of loads that may be met and of other occurrences such as transients and outages, The Power quality of a system defines to which level a practical supply system bear a resemblance to the ideal supply system. Voltage controlled voltage source inverters (VCVSIs) are extensively employed in, renewable energy, marine and military applications, power quality controllers, power supplies. They are at the core of applications that need an AC supply from a DC source. Hence it is necessary that they are made to be robust and efficient, particularly in faraway areas and renewable energy services where inverter breakdown can cause troublesomeness and the accessible energy is limited.

-Any load linked to the network will run suitably and efficiently if its Power Quality is decent enough. Installation operational expenses will be nominal.

- Loads linked to the network will fail or it can be said they will have a shorter lifetime if its Power Quality is bad, then, and the efficiency of the electrical installation will decrease. Installation operational expenses will be very high and the operation might not be possible at all.

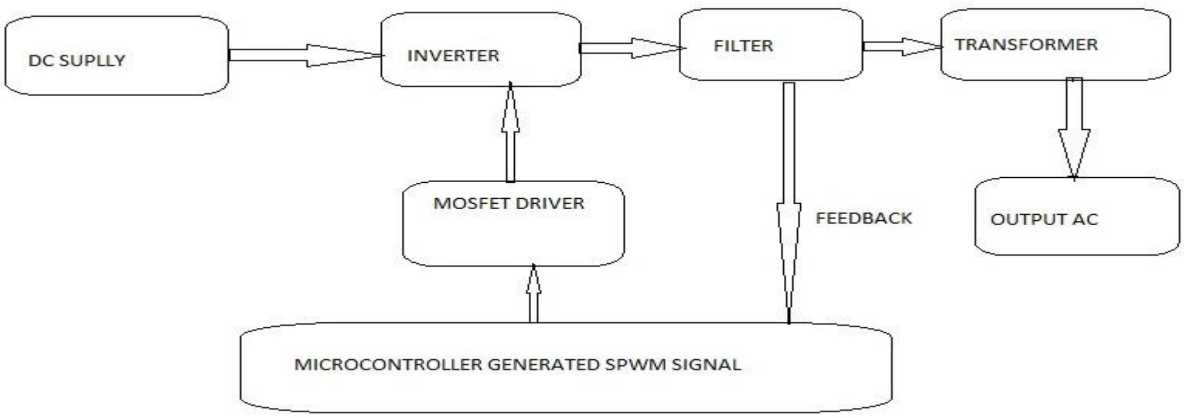


Fig.1.Block Diagram

CHAPTER 2

BACKGROUND & LITERATURE

CHAPTER 2: Background & Literature

Inverter

Inverter is a power electronics device which is used to transfer input dc power to output ac power at required frequency and voltage level.

2.1. Types of Inverter

Inverters are broadly classified into 2 types

(a)Voltage Source (VS) or Voltage Fed (VF) Inverter.

(b) Current Source (CS) or Current Fed (CF) Inverter.

2.1.1. **VSI:**

A voltage source inverter (VSI) can also be called a voltage-fed inverter (VFI).It is the one in which dc source contains minor or insignificant internal impedance .The output voltage waveform and load are independent of each other. Because of this characteristic, the VSI has numerous industrial applications like in Power system for Flexible AC Transmission (FACTS) and adaptable or adjustable speed drives (ASD)

2.1.2. CSI:

A current source Inverter (CSI), also called a current-fed inverter (CFI) requires adaptable current from a dc source of large internal impedance. Mostly the load does not impacts the output current waveform. These are extensively employed in medium voltage industrial applications that need waveform of high quality.

2.2. Single Phase Inverters (Bridge Type):

2.2.1. Half Bridge Inverter: These type Inverters comprises of 2 semiconductor switches S1 and S2. The switches consist of 2 semiconductor control (SCR, IGBT, MOSFET etc.) and 2 diodes called fly back diode or freewheeling diode.

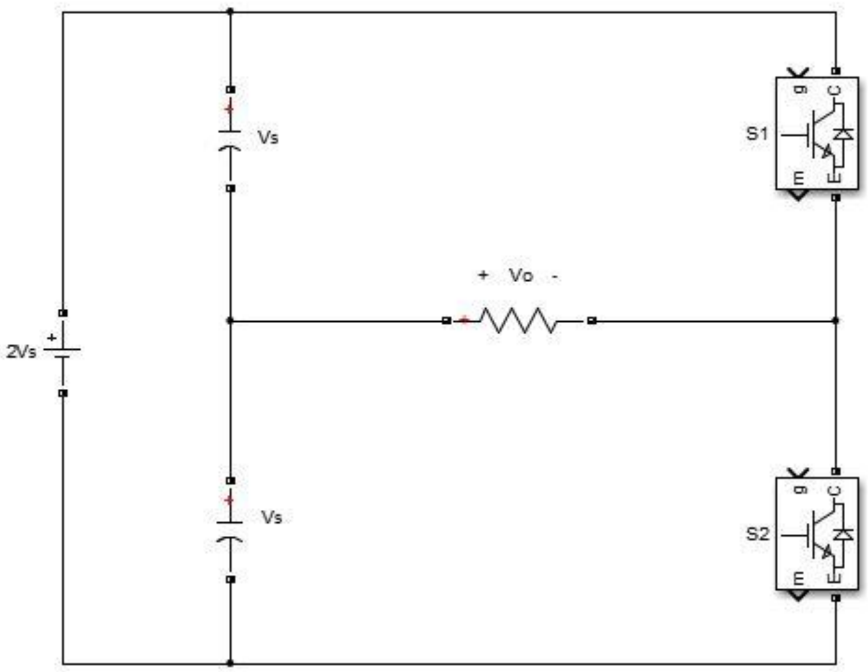


Fig.2 Circuit diagram (1- phase half bridge).

S1	S2	V_o
ON	OFF	V_s
OFF	ON	V_s

Table.1

2.2.2. Full Bridge Inverter: They comprise of double arms having twofold semiconductor controls on each of the branch. The reverse current is discharged by the antiparallel freewheeling diodes situated on the arms. The reverse load current flows through these diodes in the event of resistive-inductive load. An alternate path is given by these diodes to the inductive current which goes on to flow during the Turn OFF condition as well.

Operation

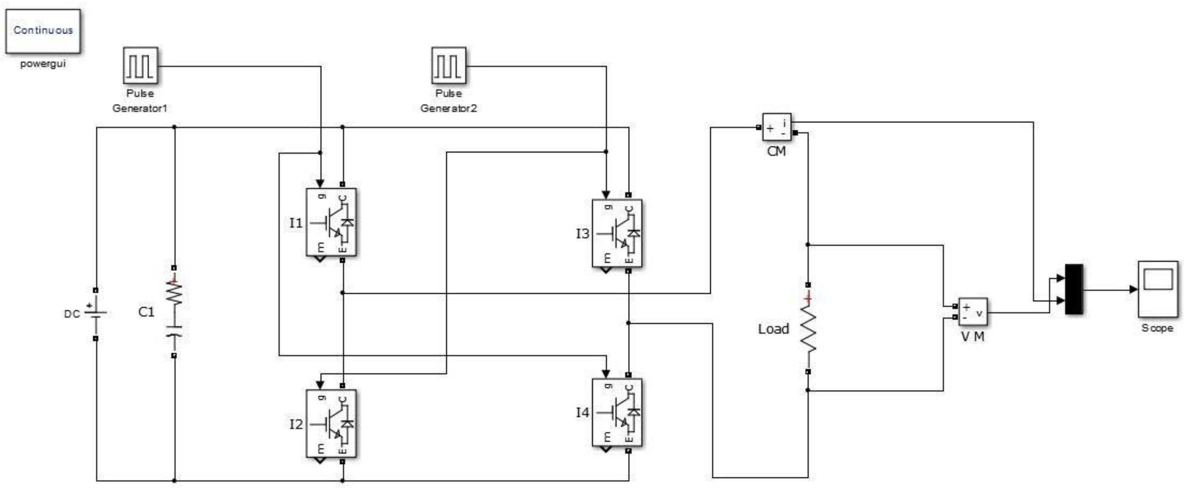


Fig.3. Circuit diagram (1- phase full bridge).

Taking Fourier Transform of output voltage (Load voltage)

$$V_0 = (4Vs/n*pi)* \sin ({}_{n}W_{s}t).$$

Where Vs = Supply voltage

n=1, 3, 5, 7…………..

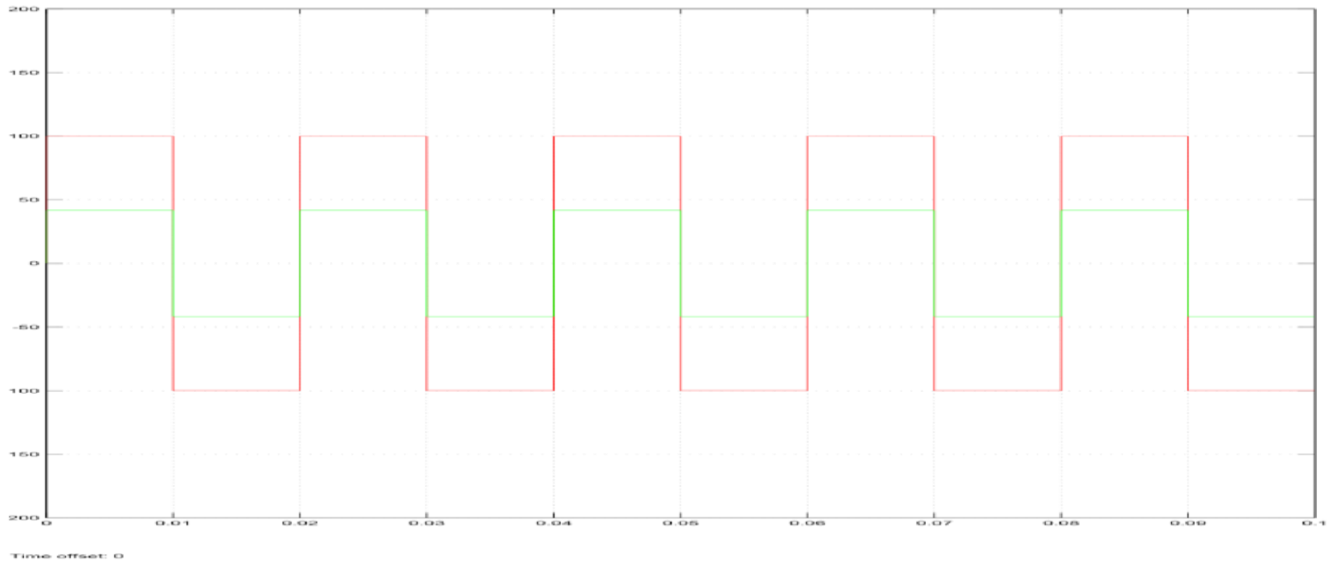


Fig.4. Output waveform for resistive load

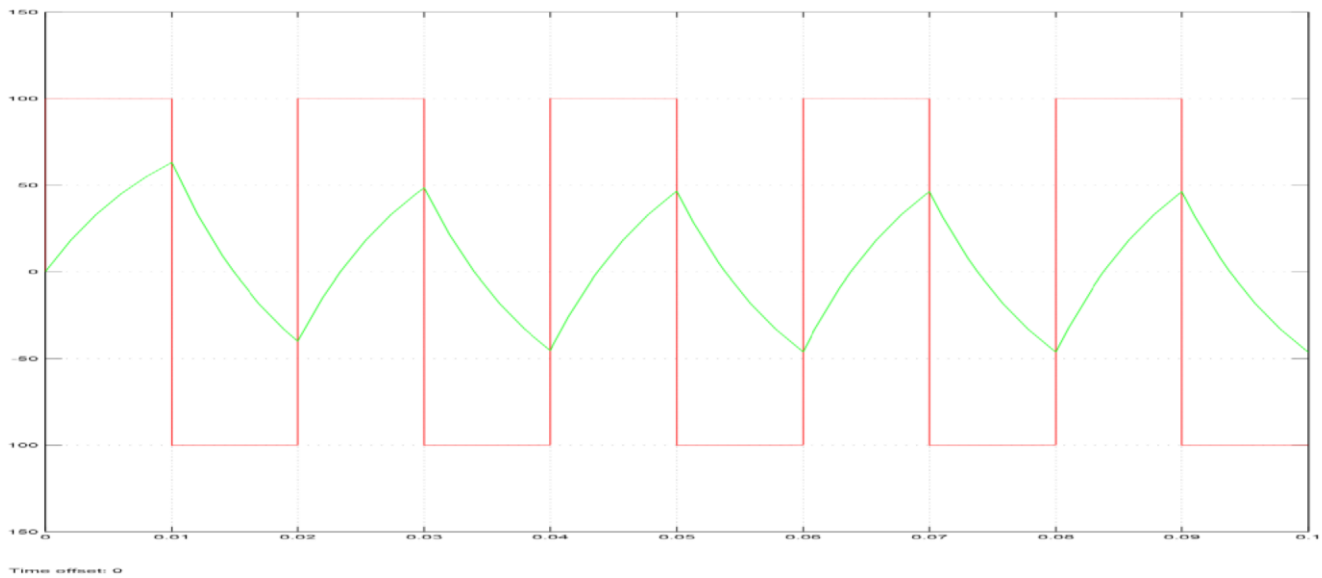


Fig.5. Output waveform for inductive load

Four switches are assembled into two groups in the switching process: I1 and I4 are in one group whereas I3 and I2 are in the other group. I3 and I2 are forced turned off as I1 and I4 are switched on. Likewise, I1 and I4 are forced off when I3 and I2 are switched on. And output here is Vo=Vs.

2.3 Voltage Control in Single phase Inverter

Constant or adjustable voltage may be needed for ac loads at their input terminals. It is crucial that output voltage of the inverters is maintained so that we realize the requisite of ac loads when such loads are driven by inverters. The voltage can be controlled by

(i) External control of ac output voltage.

(ii) Internal control of Inverter.

External control of ac output voltage

(a) Ac voltage control

The control of ac voltage controller through firing angle helps in regulating the voltage input to AC load. However higher harmonic content is seen in the output voltage. Hence the process is seldom used.

(b) Series Inverter Control

The output of two or more inverters is taken in series. The output frequency for each of the inverters needs to be same whatsoever. The output voltage for the 2-inverters is specified by,

V_0=sqrt ($V_1^2+V_2^2+2*V_1*V_2*\cos$ (theta)).

For theta=pi, V_0=0;

(ii) Internal control of Inverter.

By having a control within the inverter itself output voltage can be upheld as well from an inverter. The pulse width modulation control employed in an inverter is the most effective method of doing this.

2.4 Pulse Width Modulation

PWM techniques are described by constant amplitude pulses. We get controlled output voltage by providing dc voltage input by switching.

Advantages

I) We can obtain the output voltage control foregoing any other additional element.

II) Lower order harmonic can be eliminate or compact beside its output voltage control with this method and as we know higher order harmonics can be filtered easily.

PWM Techniques

I) Single Pulse Modulation (SPM)

II) Multiple-Pulse Modulation (MPM).

III) Sinusoidal Pulse Modulation (SPWM)

2.5.1. Single Pulse Modulation (SPM): Here a single rectangular pulse of width 2d is generated per half cycle by comparing the reference square wave signal with a triangular signal. The output voltage can be controlled by changing the pulse width 2d. This type of output voltage is called ‘quasi-square wave’.

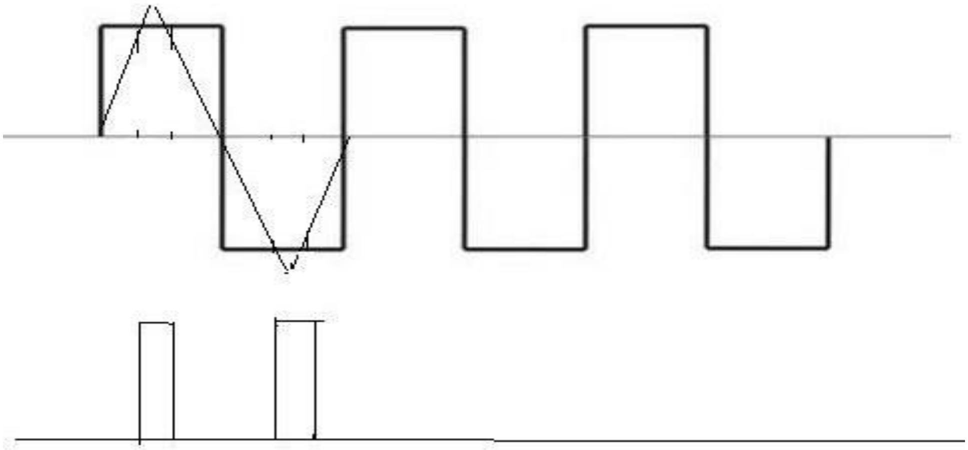


Figure.6. Single PWM waveform

2.5.2. Multiple Pulse Modulation (MPM): This is the extension of SPM as here multiple number of pulses generated per half cycle. But the reference is the Square wave signal and the carrier is a triangular signal.

fc=frequency of carrier signal

fo=output frequency

P=fc/2fo;

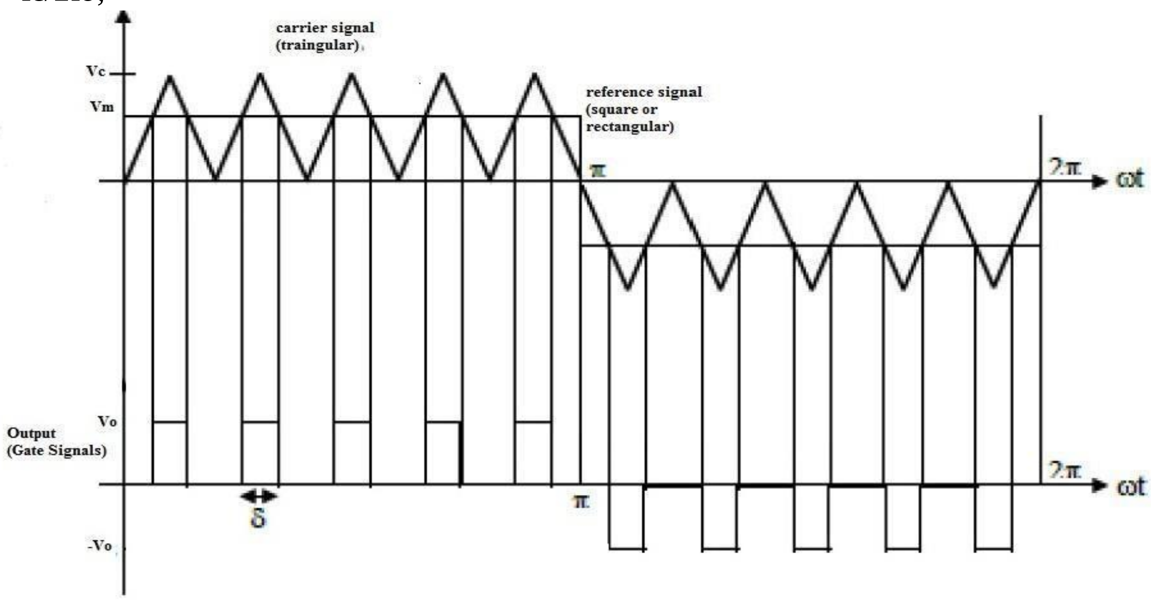


Fig.7. Multiple PWM Waveform

2.5.3 Sinusoidal Pulse Width Modulation (SPWM)

Mostly pulsed width modulation (PWM) technique is used to produce switching signal in conventional inverter design. Nevertheless, in the given design sinusoidal PWM (SPWM) is used to generate sine wave output form DC input .We characterize the SPWM technique by constant amplitude pulse with variable duty cycle for each period.

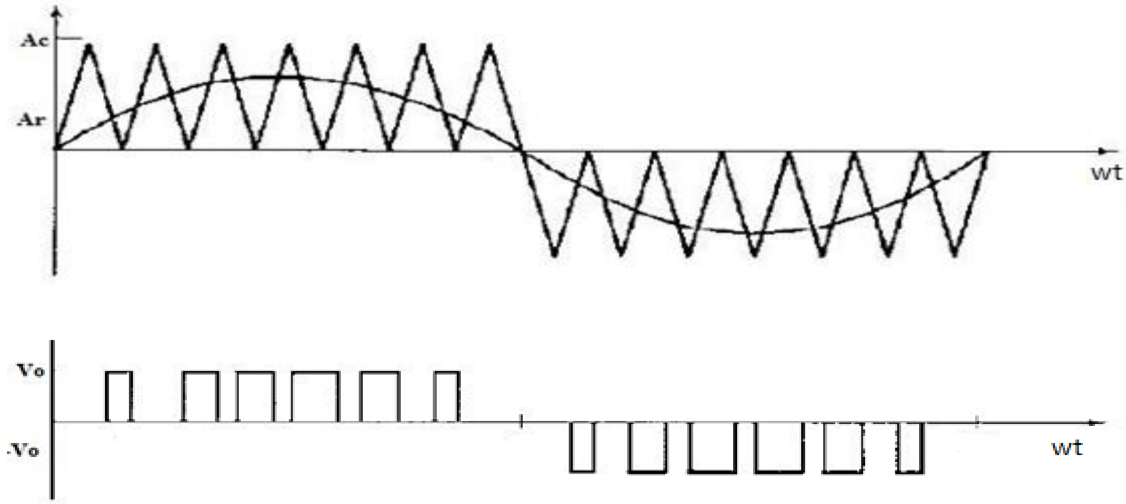


Fig8: Sinusoidal PWM Waveform.

2.5. Inverter Types (according to output waveform):

There are 3-types

(a) Square Wave Inverter

(b) Modified Square Wave Inverter

(c) True Sine Wave Inverter

2.5.1. Square Wave Inverter:

This is the basic type of inverter. The output here is a square wave as shown in below figure. But it contains huge harmonics. So it has the disadvantage of low efficiency and likely to affect some of domestic appliances.

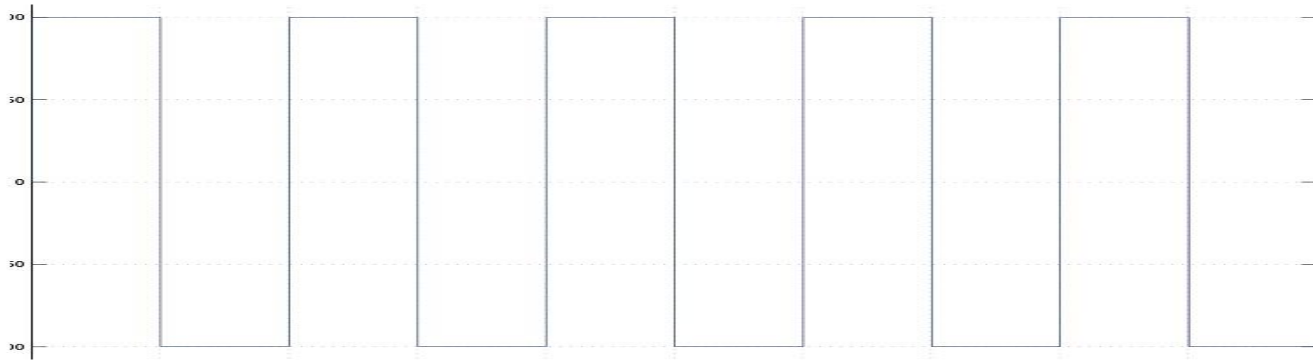


Fig.9. Output waveform

2.5.2 Modified Square Wave Inverter: A modified square wave inverter basically involves a waveform resembling a square wave, however has an additional step or so. Since sine wave in the modified form is rougher and noisier compared to a clean sine wave, clocks and timers might operate quicker or not at all work. Even if the efficiency or power will be decreased with some equipment a modified sine wave inverter will function satisfactorily with maximum equipment. However in the case of maximum of the domestic appliances it functions fine.

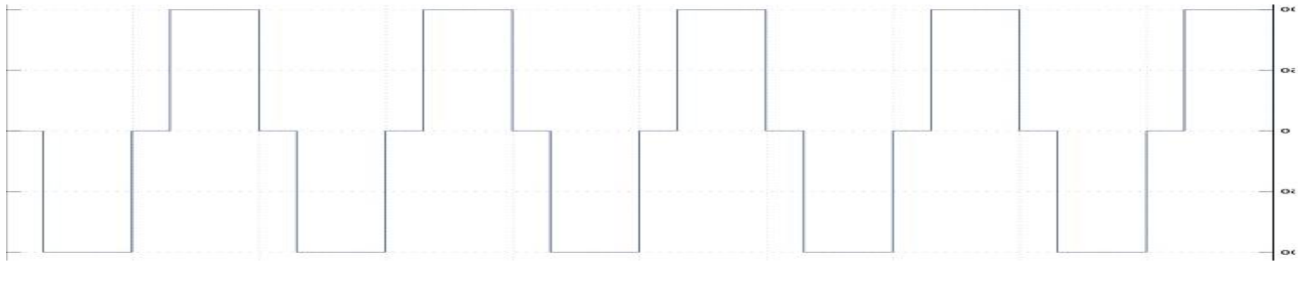


Fig10: Output Waveform

2.6.3 True Sine Wave Inverter: Inverter of this kind delivers output voltage waveform that is very analogous to the ideal voltage waveform that the Grid provides. The waveform, particularly the sine results in very less harmonic disturbance and in turn gives a very pure supply and makes it perfect for operating electrical and electronic equipment like digital fx racks, computers, and other likely sensitive systems involving no triggering issues or noise. Pure sine wave converters also maintain optimum operation of Mains battery chargers and other such things.

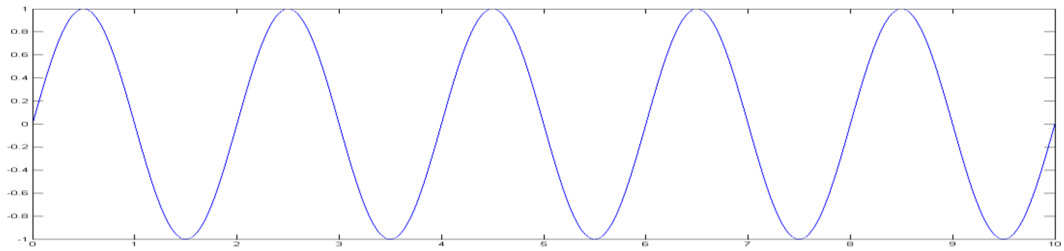


Fig11: output waveform

Benefits of using True Sine Wave Inverter:

- Most of electronics or electrical appliances are compatible for sinusoidal signal.
- Without sinusoidal supply some devices cannot produce rated output optimally (like microwave, variable motor, and refrigerator).
- Here harmonic content is of low value.

2.7. Sine Wave Generation

Pulse Width Modulation (PWM) has been the most popular and prevalent method for producing true sinusoidal Waveform. The best procedure for this is Sinusoidal Pulse Width Modulation.

This technique of PWM encompasses synthesis and production of a digital waveform. The duty cycle can be taken such that the average voltage waveform relates to a pure sinusoidal waveform for them.

By matching a high frequency triangular wave and a low power sine wave reference we can produce the SPWM signal in a very simple way. We can control switches through this SPWM signal. The output for Full Wave Bridge Inverter along a Sinusoidal Pulse Width Modulation signal will produce a wave almost identical to a sine wave with an LC filter. This practice yields a better related AC waveform as compared to others. However, there is comparatively higher extent of higher level harmonics in the waveform of the signal and the primary harmonic exists even now.

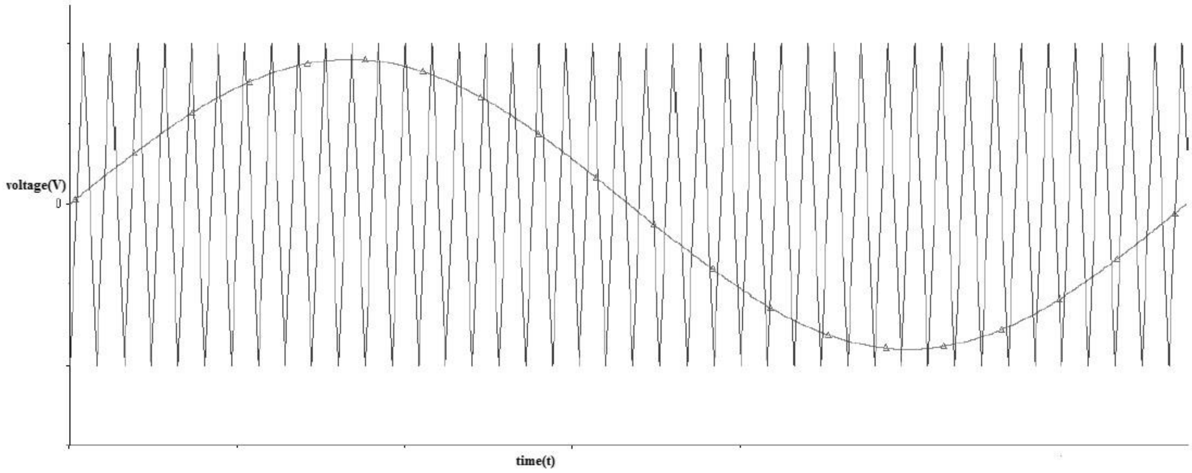


Fig12: SPWM comparison Signals

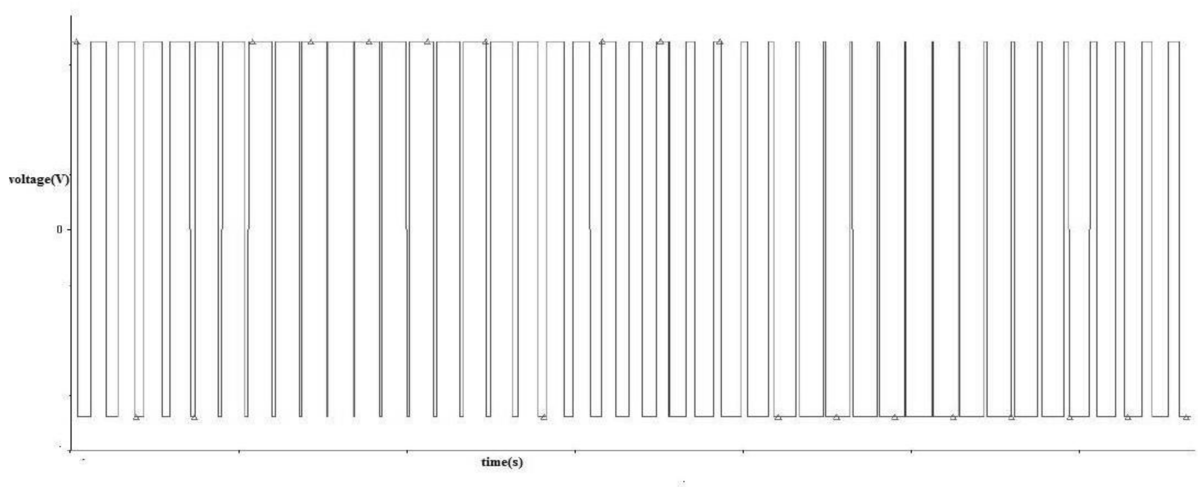


Fig13: Unfiltered SPWM output

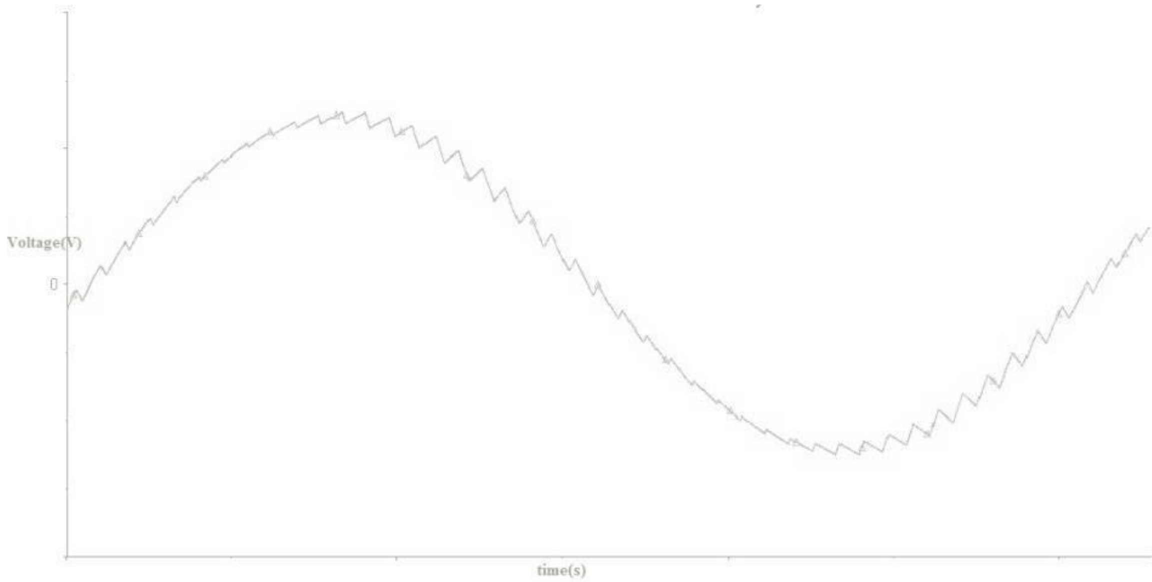


Fig14: Filtered SPWM Output

Consider the modulating signal as a sine wave with peak value A_{md}, while the peak value of the carrier that is, the triangular wave is A_{cr}, the value upon taking the division, $MI=A_{md}/A_{cr}$ is called the Modulation Index (MI). It is noted that if we control MI controls we can control the peak of the given output voltage given that there is suitably great carrier frequency. Higher amount of switching per cycle are implied by a greater carrier frequency and therefore enhanced energy loss.

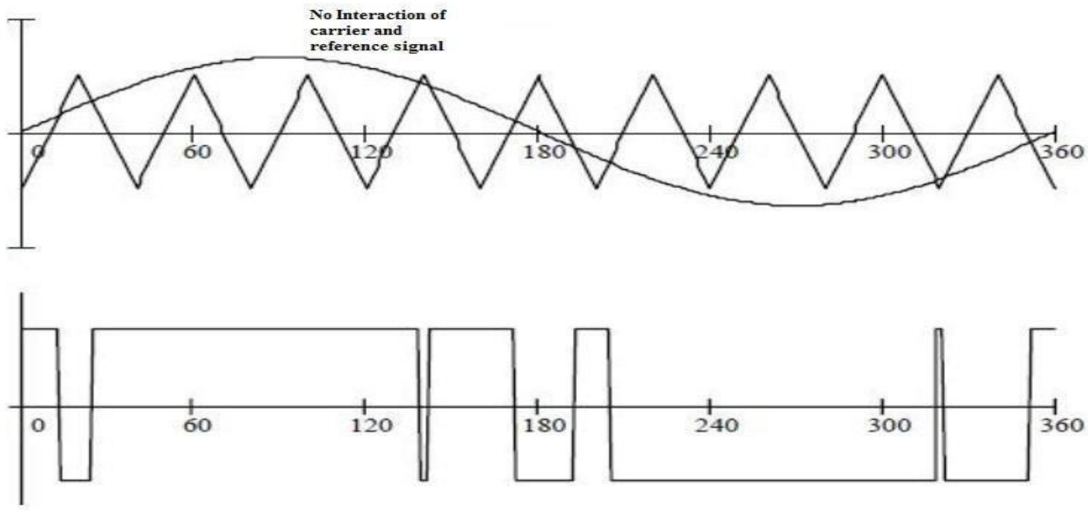


Fig15: Over modulation

The inversion procedure operates fine for MI<1 and for MI>1. It can be seen from the figure that there are periods of the triangular wave where there is no crossing of the signal and the carrier. Nevertheless, the referred “over modulation” in a certain amount is time and again accepted in the concern of attaining a high AC voltage scale even if the spectral content corresponding to voltage is weak.

2.8 Sinusoidal Pulse Width Modulation Advantages and Disadvantages:

Advantages:

- Easy to implement and control.
- Low power consumption.
- It is compatible with today’s digital microprocessors.
- Energy efficiency is high reaching to the extent of 90%.
- The power holding ability is high.

  There is not any temperature change. Also there is no drift or slump in linearity due to ageing.

Disadvantages:

- Generation of high-frequency harmonic components
- Radically augmented switching frequencies leading to larger strains on related switching equipment and hence derating concerning them.

- . Attenuation regarding the wanted fundamental component of the waveform

CHAPTER 3

METHODOLOGY

CHAPTER 3: Methodology

3 .1 : Filter Design

We need a low pass LC filter at the output end of Full Bridge Voltage Source Inverter to decrease the disturbance of harmonics due to the pulsating modulating wave. The limiting frequency is selected so that maximum of the disturbance regarding lower level harmonics are removed while designing L-C filter. To function as a voltage source which is perfect, it implies zero extra distortion of voltage even when there is variation of load or the load is nonlinear, the impedance for the inverter at the output is essentially made null. So, at the chosen cut-off frequency, inductance needs to be minimized while capacitance parameter needs to be maximized for the low-pass filter. All values for L and C components are found out to reduce the reactive power regarding the constituents as for L and C their reactive power shall govern the economical aspect for the LC filter and it is carefully chosen to decrease the expense, then it is normal that the filter constituents evaluated at the range of a low impedance is zero. On the other hand a high value of inductance and capacitance and subsequently the impedance for the inverter at the output is large to a high extent when a little variation in the load or nonlinearity in the load is considered. The inverter’s output voltage waveform might be sinusoidal in case of the load’s linearity or else steady state situation under these design values for the voltage waveform at the output will be distorted effected by the system’s slow response because of the non-zero response at the output.

For the single phase Pulse Width Modulation-Voltage Source Inverter Figure 1 displays the power circuit considering any linear or nonlinear load. Load current otherwise flows dependent on the type of loads such as linear and nonlinear load. Hence it is tough to denote the inverter voltage to load current in terms of the transfer function.

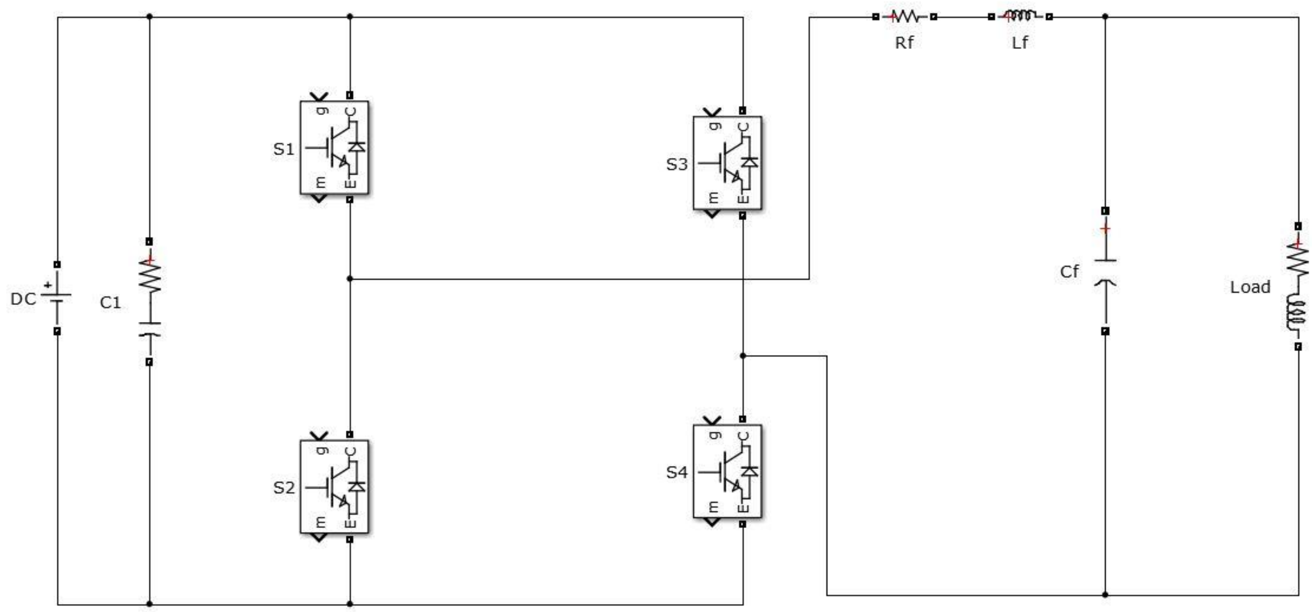


Figure 16: Inverter with LC Filter

The linearity property is fulfilled as the plant has L-C low-pass filter, thus it is likely to denote the system having double inputs of load current and inverter output voltage.

By means concerning the closed association among the capacitor's filter value in relation to the time constant of the system, the value of the capacitor can be evaluated. We can calculate the impact to the distortion in voltage due to the load current from the closed loop form. We have the likelihood to study the amount of distortion of voltage waveform in the system for a load's nonlinearity.

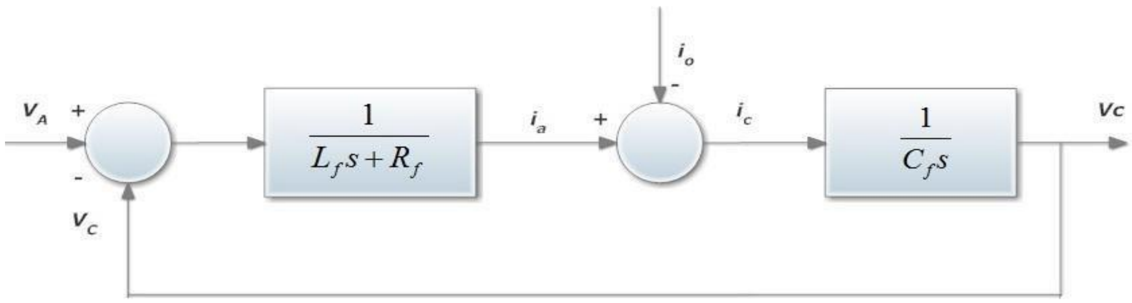


Fig 17: Block Diagram for single phase Pulse Width Modulation-Voltage Source Inverter

In Figure 17, the block diagram for the system concerning the single phase **Pulse Width Modulation-Voltage Source Inverter** and the transfer function for the input and output is shown

$$V_c(s)=\frac{1}{L_fC_fs^2+jR_fC_f}V_A(s)-\frac{L_fs+R_f}{L_fC_fs^2+jR_fC_fs+1}I_o(s) \tag{3.1.a}$$

The transfer function for the frequency may be conveyed as

$$V_c(j\omega)=\frac{1}{1-L_fC_f\omega^2+jR_fC_f\omega}V(j\omega)-\frac{jL_f\omega+R_f}{1-L_fC_f\omega^2+jR_fC_f\omega}I_o(j\omega) \tag{3.1.b}$$

Determination of the transfer function:

$$Va(s)-sL_fIa(s)-R_fIa(s)-Vc(s)=0 \tag{3.1.c}$$

$$Va(s)-Vc(s)=Ia(s)(sL_f+R_f) \tag{3.1.d}$$

$$\frac{Va(s)}{Vc(s)}=1+\frac{Ia(s)(sL_f+R_f)}{Vc(s)}$$

(3.1.e)

$$\frac{Va(s)}{Vc(s)}=1+\frac{Ia(s)(sL_f+R_f)sC_f}{Ic(s)}$$

Since $i_a=i_c+i_o$ (3.1.f)

$$Ia(s)=Ic(s)+\frac{Vc(s)}{Z_L} \tag{3.1.g}$$

$$\frac{Ia(s)}{Ic(s)}=1+\frac{1}{sC_fZ_L} \tag{3.1.h}$$

$$\frac{Va(s)}{Vc(s)}=1+(1+\frac{1}{sC_fZ_L})(sL_f+R_f)sC_f \tag{3.1.i}$$

$$\frac{Va(s)}{Vc(s)}=\frac{s^2L_fC_f+sL_f+R_fC_fsZ_L+R_f+Z_L}{Z_L} \tag{3.1.j}$$

$$\frac{Vc(s)}{Va(s)}=\frac{Z_L}{s2L_fC_f+sL_f+RCsZ_L+R_f+Z_L} \tag{3.1.k}$$

Currently, we can find the step response through transfer function. From bode plot we can get corner or cross over frequency while from root locus method stability can be found.

We can calculate the amplitude of the voltage harmonics at the filter output by summing the two harmonics due to the inverter output voltage and the load current.

We can simplify the above equation by ignoring the imaginary part in both the terms since equivalent series resistance of inductor is very minor which means

$$|1-L_f C_f \omega^2| >> |R_f C_f \omega| \tag{3.1.l}$$

So,

$$V_c(j\omega) = \frac{1}{1-L_f C_f \omega^2} V(j\omega) \tag{3.1.m}$$

For the conventional output filter module technique, we consider the load current **as** the disturbance. Consequently we can neglect it.

We can apply the filter design method to the load which is linear. Nonetheless for the loads that are nonlinear or transient load change, we cannot ignore the output current term because of the rise of load current harmonics. Hence, it should be considered in case of study of voltage harmonics under the nonlinearity of the load.

We ought to minimize the inductor value and on the other hand maximize the value of the capacitor at the identical limiting frequency so as to be independent of the load current. Hence after it fulfills the null output impedance and functions **as** a perfect voltage source.

At Cut-off frequency

$$\frac{V_C(j\omega)}{V_A(j\omega)} = \frac{1}{1-L_f C_f \omega^2} \tag{3.1.n}$$

We should limit the output of the filter to input voltage harmonics to be within 3%.

Hence,

$$\frac{V_C(j\omega)}{V_A(j\omega)} = 3\% \tag{3.1.o}$$

$$\frac{1}{1-L_f C_f \omega^2} = 0.03 \tag{3.1.p}$$

$$\left| \frac{1}{f^2 \frac{X_L}{X_C} - 1} \right| \le 0.03$$

$$\frac{X_L}{X_C} \ge \frac{34.2}{f^2}$$

Where f=corner or cut-off frequency

So, from this we can find out the L and C for the filter

From the equation

Substituting $Z_l = 2.5$ *ohm*

$C_f = 1$ *mF*

$L_f = 10$ *mH*

$T(s) = K/(s^2 + 400s + K)$; $K = 100000$

Bode plot of T(s)

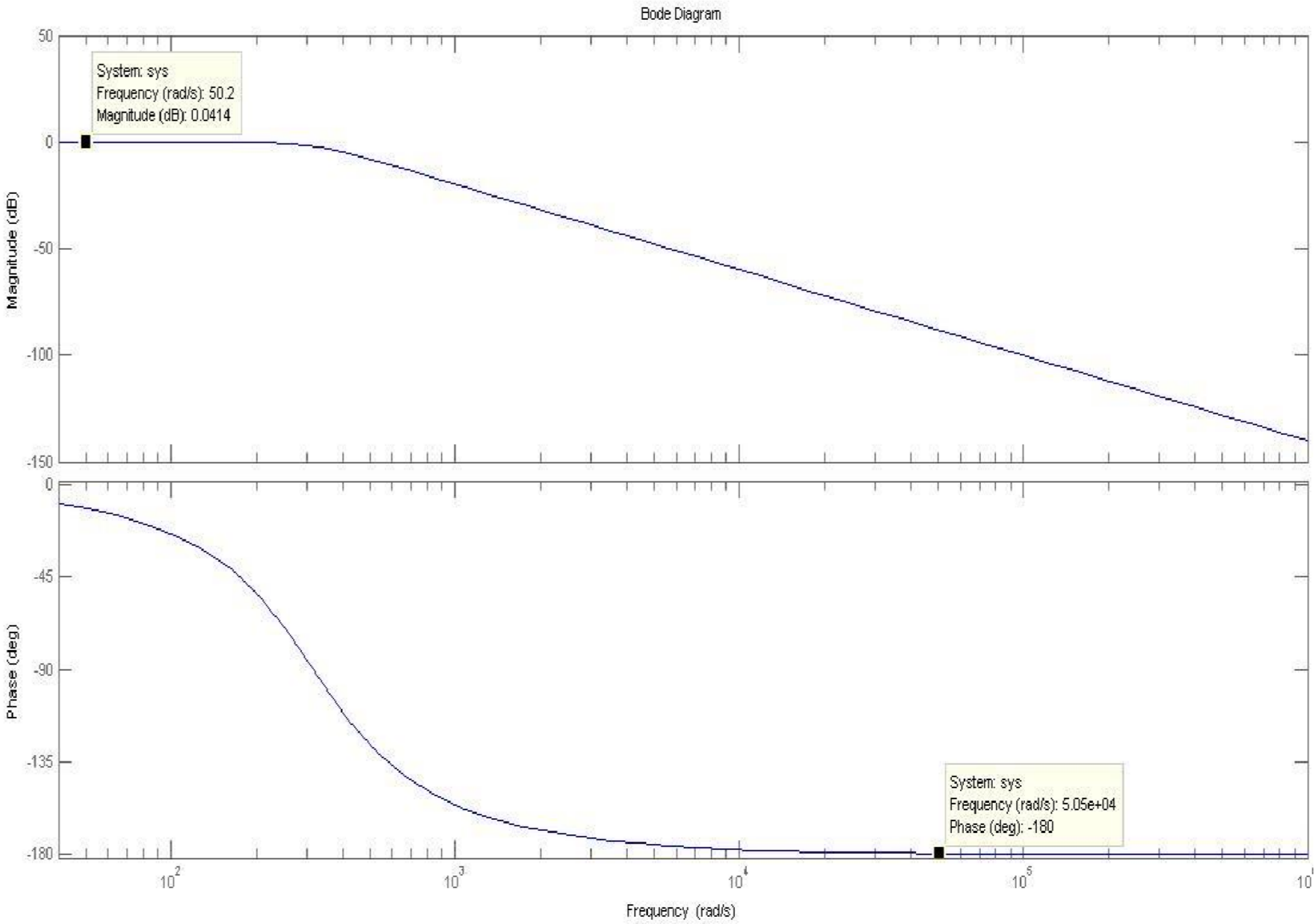


Fig 18. Bode plot of Transfer function

3.2 Parasitics calculation for Designed Inverter

Any unwanted or undesirable element of the circuit (resistance, capacitance or inductance) in an electrical circuit is called as parasitic element. The value that we have designed for the circuit element is changed due to this parasitic element resulting in the reduction of the device efficiency and also it leads to hindrance of the energy flow giving rise to the undesirable energy losses. Thus, we must consider the parasitics as we design any circuit. That circuit needs to be prepared in a way so as the value that we have considered for the parasitic elements must be marginal. For determining the parasitics in VSI we have devised the following method.

Mathematical Modelling

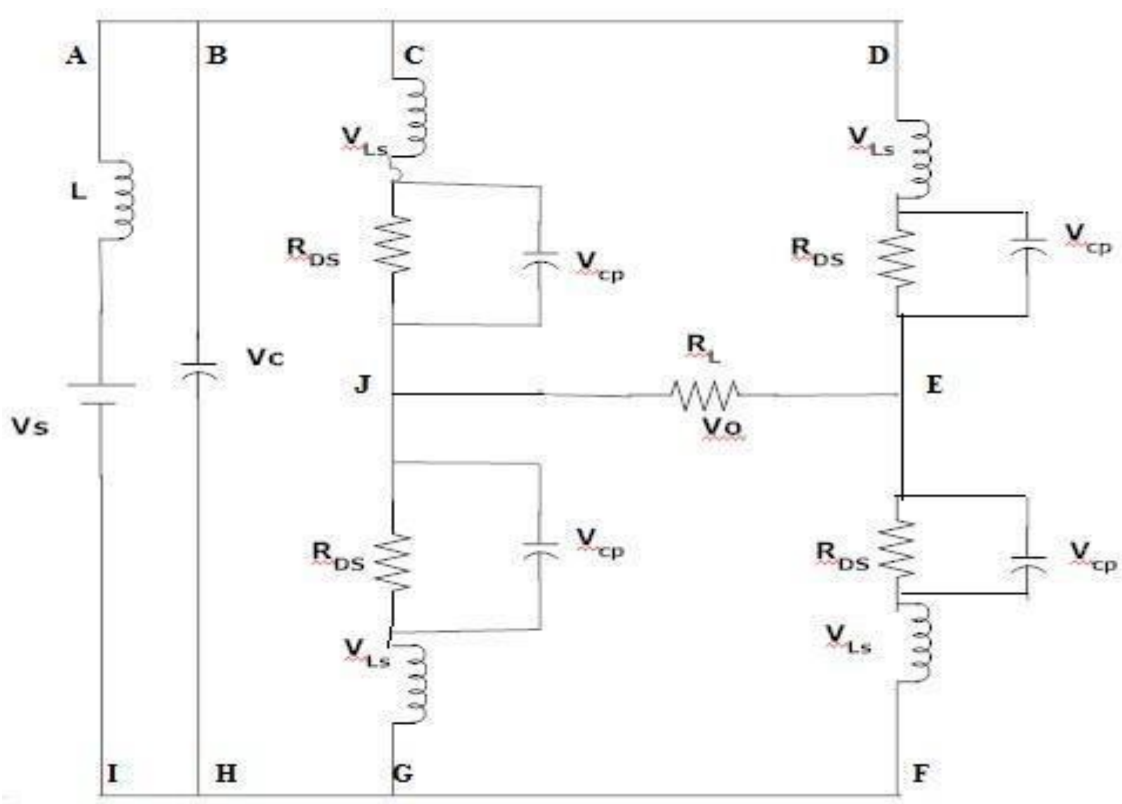


Fig 19: Voltage Source Inverter taking parasitics

We propose the model of single-phase full–bridge inverter with parasitic elements. The study is separated into two portions; one concerns the turn-on state while the second concerns the turn-off state.

L= Parasitic inductance between source and input capacitance

Ls= Stray inductance of the wiring

R_{DS}=Drain-Source resistance

Cp=Parasitic capacitance

We apply KVL to ABHI

$$V_s = v_L + v_c \tag{3.2.a}$$

We apply KVL to BCJEFG

$$v_c = vo + 2 * v_{Cp} + i_{Ls} * R_L \tag{3.2.b}$$

$$v_c = 2Ls \frac{di_{Ls}}{dt} + 2v_{cp} + i_{Ls} * R_L \tag{3.2.c}$$

We apply KCL

$$i_{Ls} = i_{R_{DS}} + i_{Cp} \tag{3.2.d}$$

$$i = i_c + i_{Ls} \tag{3.2.e}$$

As,

$$i_{RDS} = \frac{v_{Cp}}{R_{DS}} \tag{3.2.f}$$

$$i_{Cp} = C_P \frac{dv_{Cp}}{dt}$$

(3.2.g)

$$i_{Ls} = \frac{v_{Cp}}{R_{DS}} + C_P \frac{dv_{Cp}}{dt}$$

We assume same device parameters as well as parasites (3.2.h)

A. Parasitic Capacitance Voltage

$$v_{Cp} = \frac{v_c}{2} - Ls \frac{di_{Ls}}{dt} - \frac{v_o}{2} \quad (3.2.i)$$

$$v_{Cp} = \frac{v_c}{2} - Ls \frac{d}{dt}\left[\frac{v_{Cp}}{R_{DS}} + Cp \frac{dv_{Cp}}{dt}\right] - \frac{v_o}{2}$$

(3.2.j)

$$\frac{v_c - v_o}{2L_sC_p} = \frac{d^2v_{Cp}}{d^2t} + \frac{dv_{Cp}}{R_{DS}C_Pdt} + \frac{v_{Cp}}{L_sC_p}$$

(3.2.k)

CASE I: Natural Response

$$A^2 + \frac{A}{R_{DS}C_p} + \frac{1}{L_sC_p} = 0$$

(3.2.l)

$$A^1, A^2 = -\frac{1}{2R_{DS}C_p} \pm \sqrt{(\frac{1}{2R_{DS}C_p})2 - \frac{1}{L_sC_p}}$$

(3.2.m)

CASE II: Forced Response

$$\frac{d^2k}{dt^2} + \frac{1}{R_{DS}C_p}\frac{dk}{dt} + \frac{k}{LsCp} = \frac{v_c - v_o}{2L_sC_p}$$

(3.2.n)

Hence, the result of forced equation is

$$k = \frac{v_c - v_o}{2R_{DS}}$$

(3.2.o)

B. Parasitic Inductive Current

$$\frac{v_c - v_o}{2R_{DS}L_sC_p} = \frac{d^2 i_{Ls}}{dt^2} + \frac{di_{Ls}}{R_{DS}C_p dt} + \frac{i_{Ls}}{L_sC_p} \qquad (3.2.p)$$

CASE I: Natural Response

$$A^2 + \frac{A}{R_{DS}C_p} + \frac{1}{L_sC_p} = 0 \qquad (3.2.q)$$

$$A^1, A^2 = -\frac{1}{2R_{DS}C_p} \pm \sqrt{(\frac{1}{2R_{DS}C_p})2 - \frac{1}{L_sC_p}} \qquad (3.2.r)$$

CASE II: Forced Response

$$\frac{d^2k}{dt^2} + \frac{1}{R_{DS}C_p}\frac{dk}{dt} + \frac{k}{LsCp} = \frac{v_c - v_o}{2L_sC_p} \qquad (3.2.s)$$

The outcome of force response is

$$\frac{v_c - v_o}{2R_{DS}} = k \qquad (3.2.t)$$

CASE III: Complete Response

Mode 1: T1 and T2 (Turn ON)

$$i_{LS}(t) = i_{LN} + i_{LF} \qquad (3.2.u)$$

$$i_{Ls}(t) = e^{\alpha t}(Be^{\beta t} + Ce^{-\beta t}) + \frac{v_c - v_o}{2R_{DS}} \qquad (3.2.v)$$

$$\alpha = -\frac{1}{2R_{DS}C_p} \qquad (3.2.w)$$

$$\beta = \sqrt{(\frac{1}{2R_{DS}C_p})^2 - \frac{1}{L_sC_p}} \qquad (3.2.x)$$

$$v_{Cp}(t) = i_{Cp}(t) * R_{DS} \qquad (3.2.y)$$

Mode2: T1 and T2 (Turn OFF)

$$v_{Cp}(t) = v_{CN} + v_{CF} \tag{3.2.z}$$

$$v_{Cp}(t) = e^{\alpha t}(Y\cos\beta t + Z\sin\beta t) + \frac{v_C - v_O}{2} \tag{3.2.z.1}$$

The parasitic inductance and parasitic capacitance can be determined through these equations. Consequently, we should propose the design such that the parasitics effects are minimized so that the efficiency of the inverter is maintained and there is smooth flow of energy in the circuit.

3.3. PI Control

For delivering greater control as compared to customary PWM or SPWM, we employ Proportional Integral (PI). The switching frequency needs to be fixed and must not depend on output frequency so as to get a smooth required waveform at the output side and which we can get by Proportional Integral Control.

Benefits that Proportional Integral Control offers:

- We get constant inverter switching frequency that results in identified harmonics.
- Wave shaping and immediate control.

3.3.1. PI Control Structure:

As a load gets linked to the output of the inverter, means sensors sense the output voltage taken at the load side. This voltage goes to a comparator or subtractor as feedback that then matches the load output in comparison to the reference signal (desired signal) which in turn yields the voltage error signal. A proportional-integral (PI) controller receives this instantaneous error. The tracking is improved by the integral term in the PI controller by decreasing the instantaneous error amongst the reference and the actual voltage. There is a range within which the error has to remain .The boundary is given by the peak value corresponding to the triangular wave.

An error value results which is to be matched to a triangular carrier signal and their crossings give pulse width and the switching frequency.

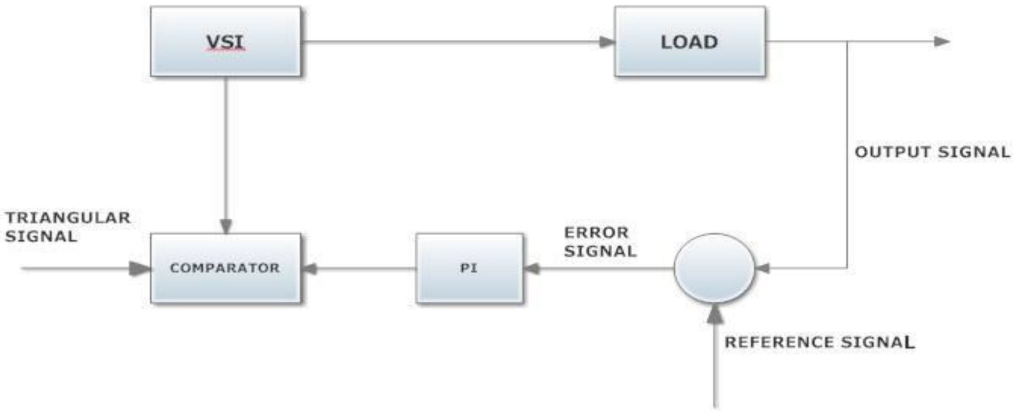


Fig 20: VSI with PI Controller

The error value is detected by the Proportional Integral controller which is the type of controller giving feedback. The subtraction of the reference or desired signal from the output signal is mainly the error value. This error is minimized by the PI controller which functions to controlling the system inputs. There are two elements of PI controller specifically Proportional (P) and Integral (I). The error is minimized by the Proportional part while the offset is lessened by the Integral part. P relies on existing error and I relies on previous errors. Thus, step response for the system could be enhanced by means of Proportional Integral controller.

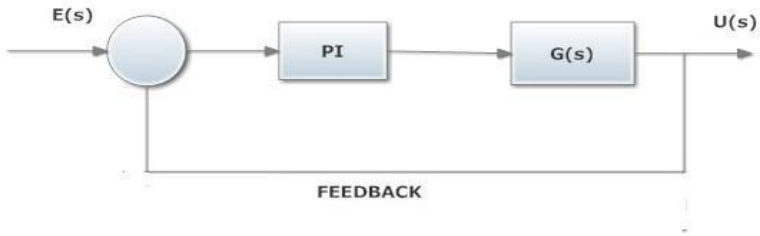


Fig 21: PI Control

The new response of the system after installing a PI Controller block will be

$$\frac{U(s)}{E(s)} = PI * G(s)$$

$$PI = Kp + \frac{Ki}{s}$$

$$\frac{U(s)}{E(s)} = (Kp + \frac{Ki}{s}) * G(s)$$

Currently Proportional Integral element gains, Kp(proportional gain) and Ki(integral gain) must be adjusted to attain a improved system reaction. The influence of each of the parameters value on growing is stated as under.

Response	Rise Time	Overshoot	Settling Time	Steady State Error
k_p	Reduction	Rise	Minor variation	Reduction
k_i	Reduction	Rise	Increase	Elimination

Table 2: Proportional Integral Tuning

CHAPTER 4

RESULTS &CONCLUSION

CHAPTER 4: Results & conclusions

4.1 Results of Simulation

4.1. 1. Simple Inverter

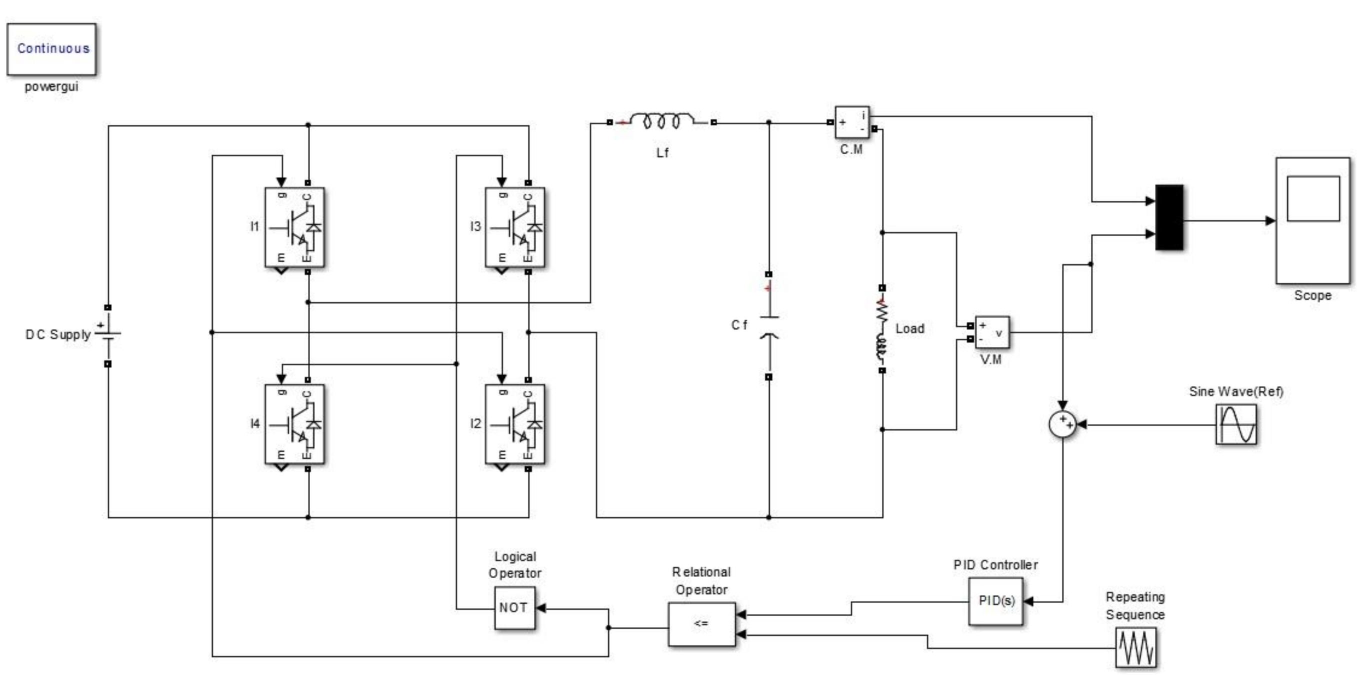


Fig.22. Simulation circuit tracking output voltage

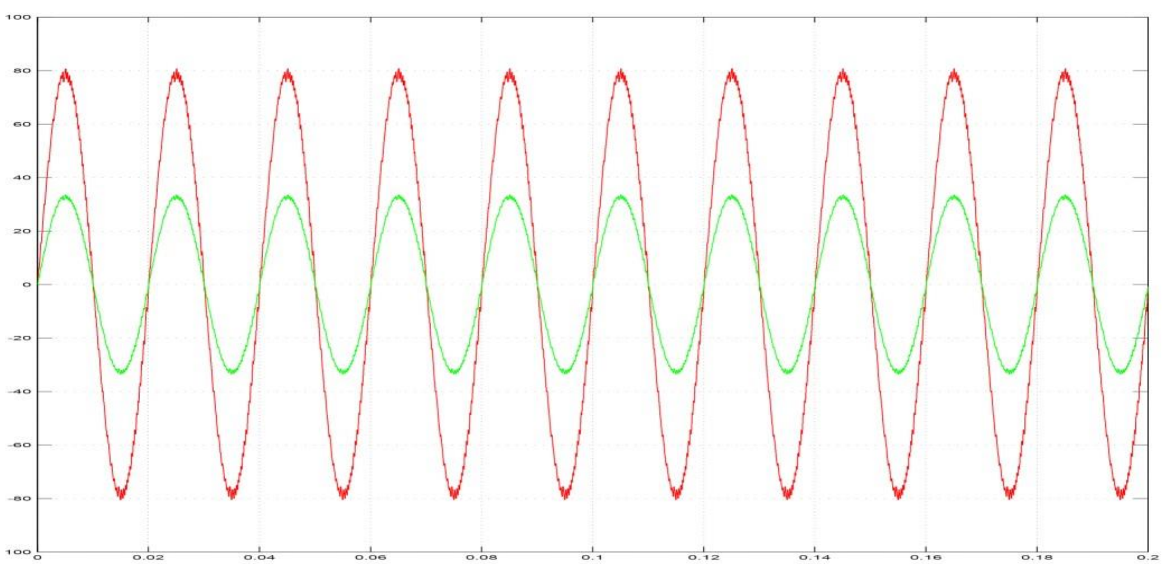


Fig.23.Output voltage and current waveform for ‘R’ Load

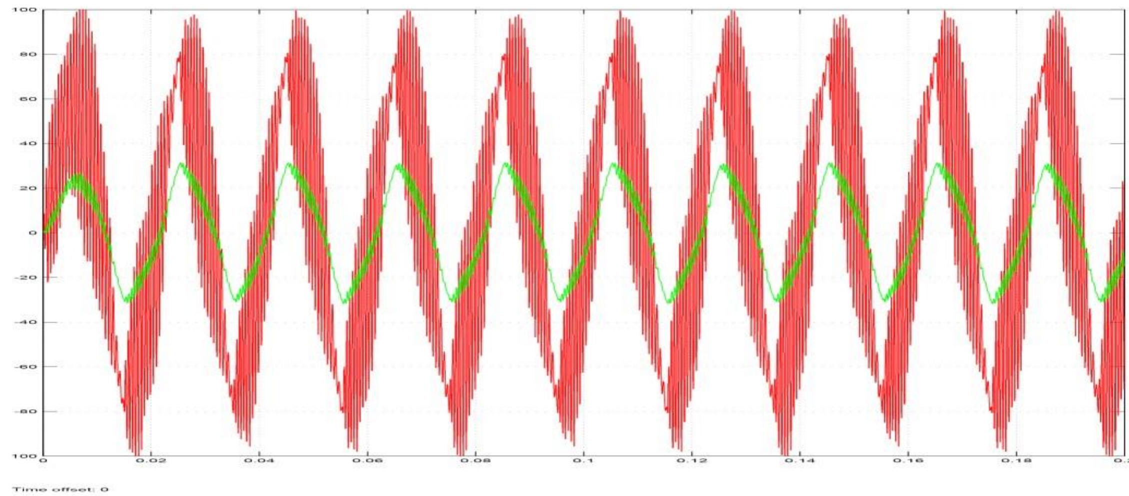


Fig.24.Output voltage and current waveform for ‘RL’ Load

As from the above simulation we found that current is distorted with RL Load; now we are trying to track the inductor current with the same circuit parameters.

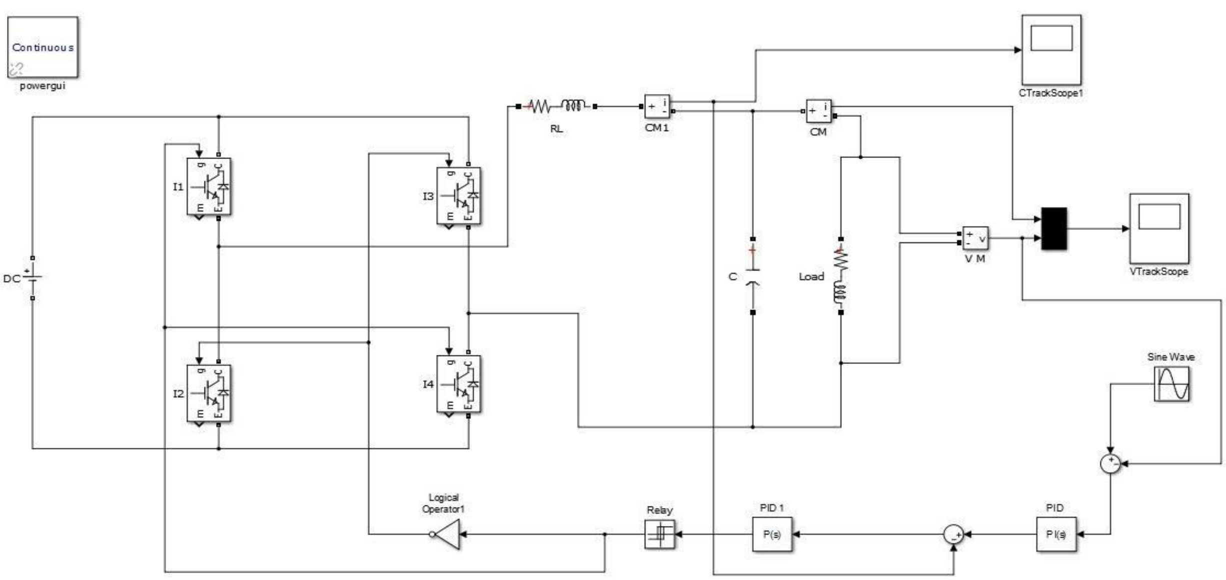


Fig.25.Simulation circuit taking inductor current

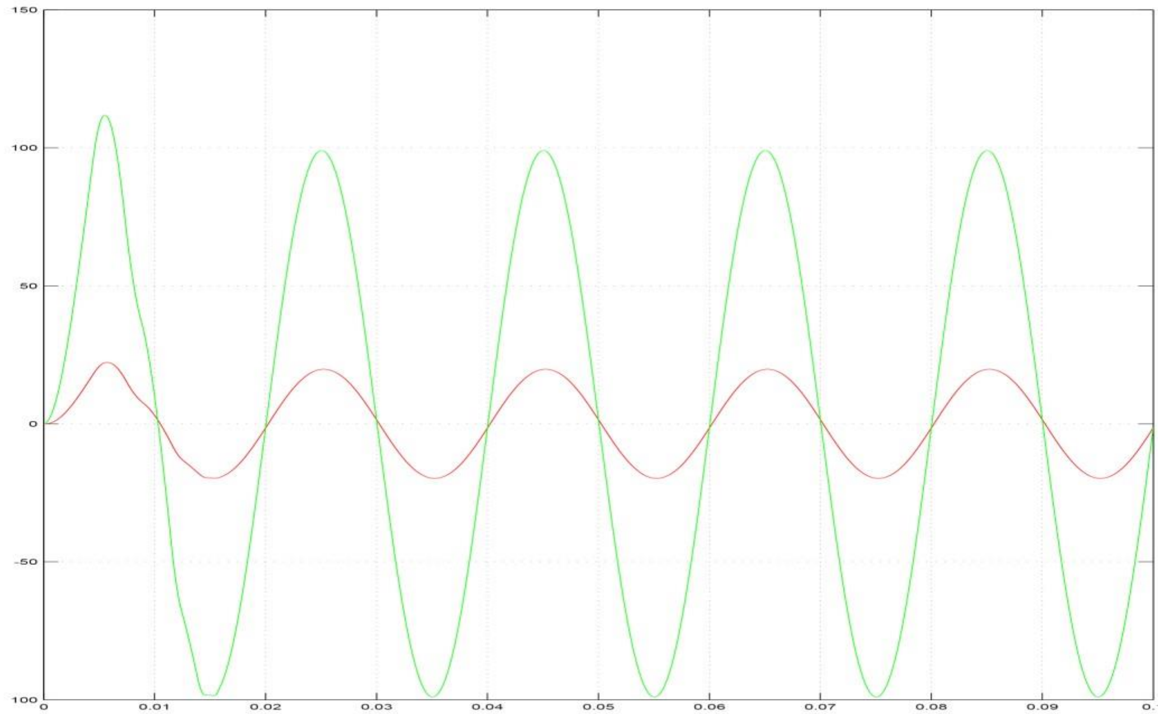


Fig: 26. Output waveform with RL Load

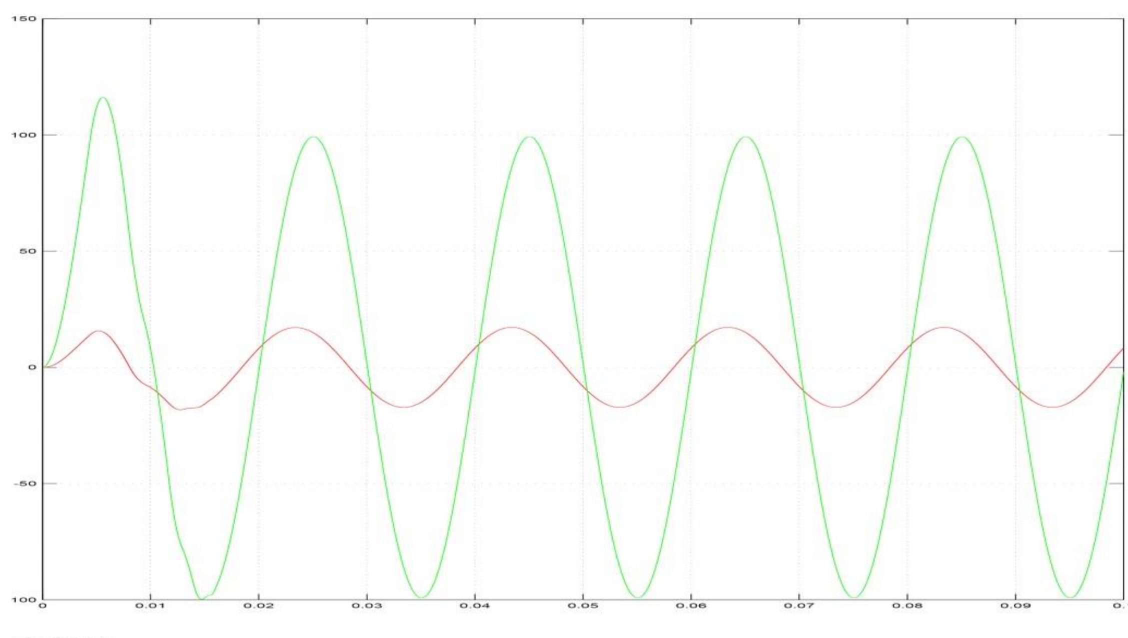


Fig: 27. Output waveform with RLC Load

Practical Inverter (Simulink Model)

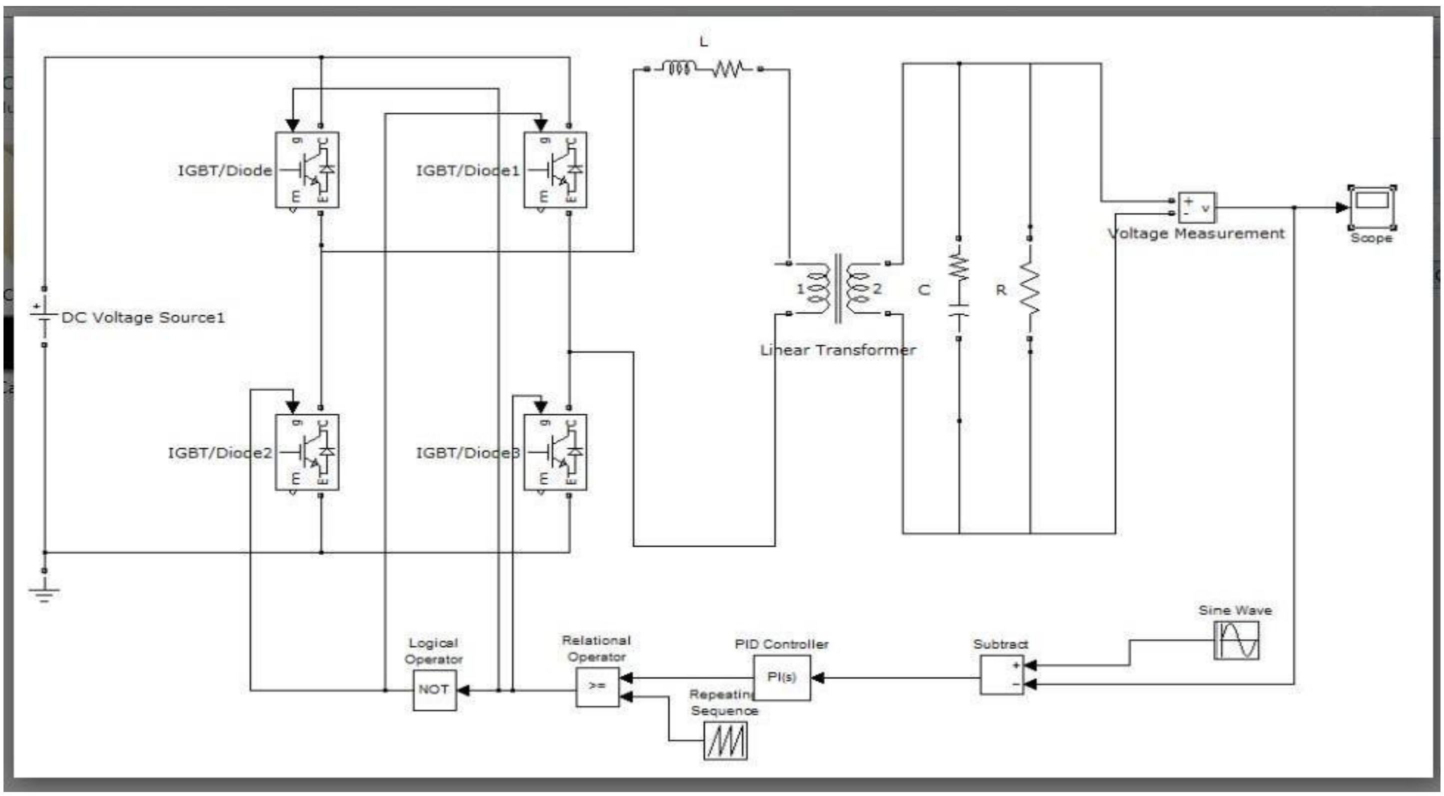
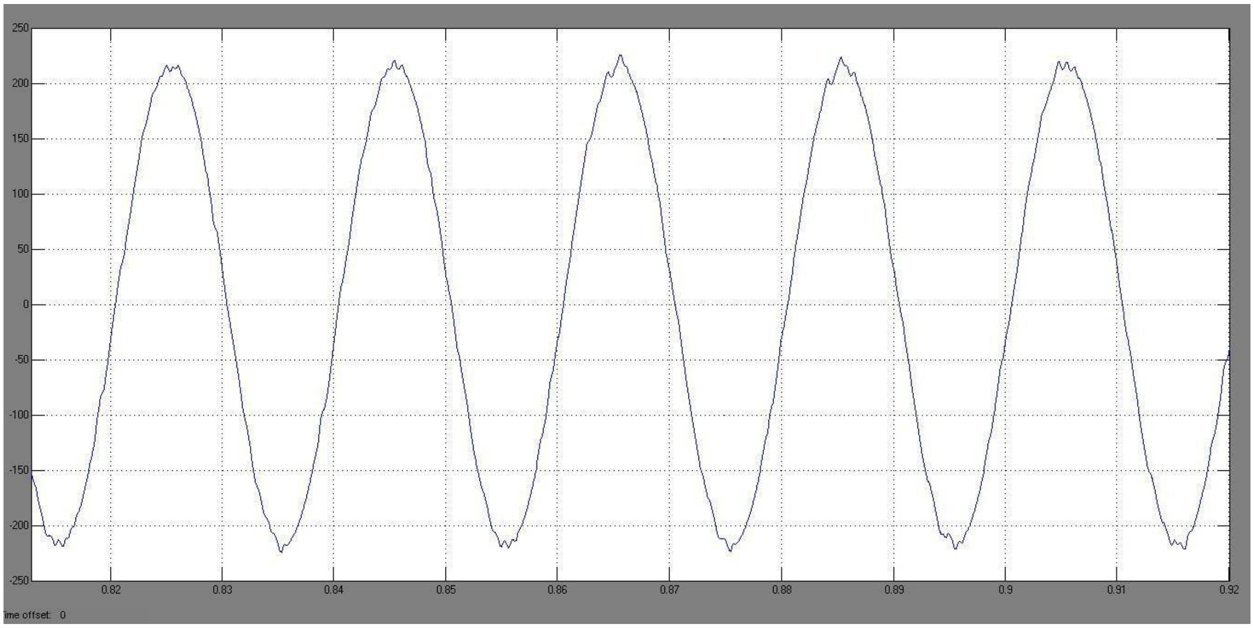
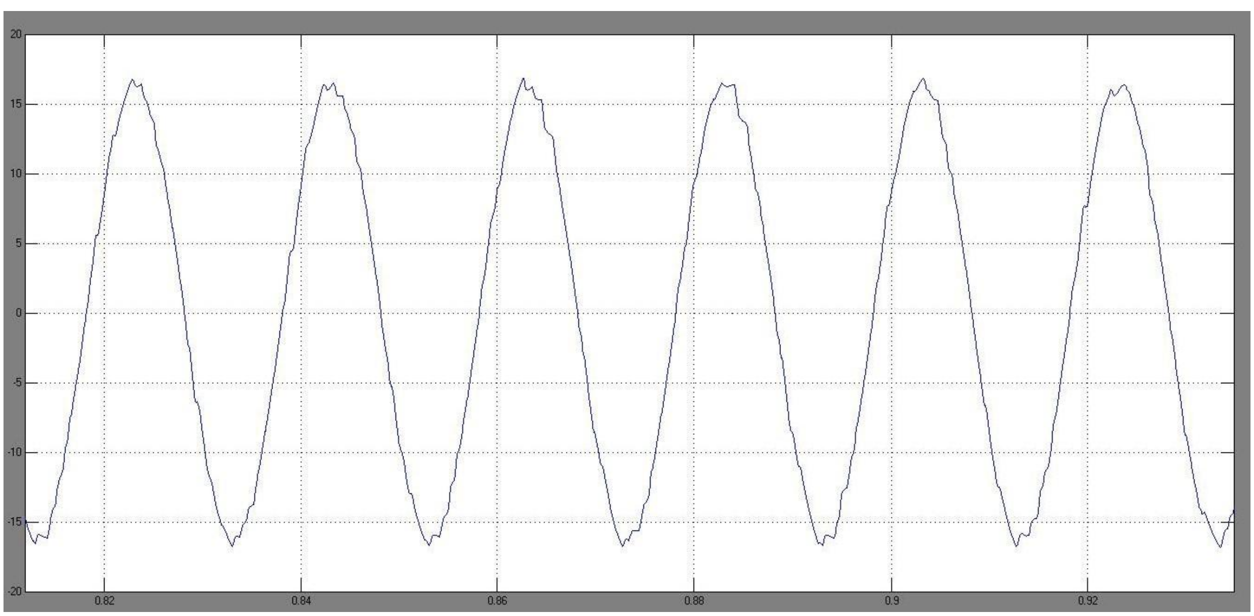


Fig 28: Practical circuit of Inverter.

Voltage Waveform



Current Waveform



4.2. Conclusion

The above thesis deals with Single Phase Sinusoidal Pulse Width Modulation Voltage Source Inverter (SPWM)-VSI. It embraces the simple simulation with output voltage tracking along with current control. Its numerous parameters like L and C concerned in LC Filter design, proportional constant ($k_{p)}$ and Integral Constant ($k_{i)}$ for Proportional Integral controller and parasitic have been evaluated. We have tested them for Simulink modelling and carried out simulation. We have changed the parameters mentioned and have analyzed the subsequent voltage and current graphs.

CHAPTER 5: FUTURE WORK

Our future endeavor consists of refining the system's stable nature and also to analyze several unstable possibilities in Sinusoidal Pulse Width Modulation-Voltage Source Inverter along with the analysis of harmonics and means to reduce it and to model a real domestic Sinusoidal Pulse Width Modulation-Voltage Source Inverter with a superior design of the controller.

CHAPTER 6: REFERENCES

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